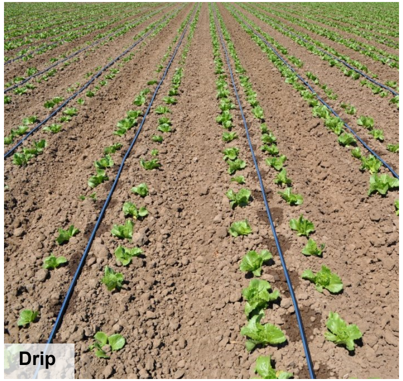
Science for resilient livelihoods in dry areas

Ultra-Low Energy Drip Irrigation for MENA Countries

Vinay NANGIA and Rachid MOUSSADEK

Design and validate low-cost, low-pressure, high-performance drip irrigation systems for smallholder farmers.



Agriculture uses 70% of the world’s freshwater, and many regions are facing water scarcity. [1]

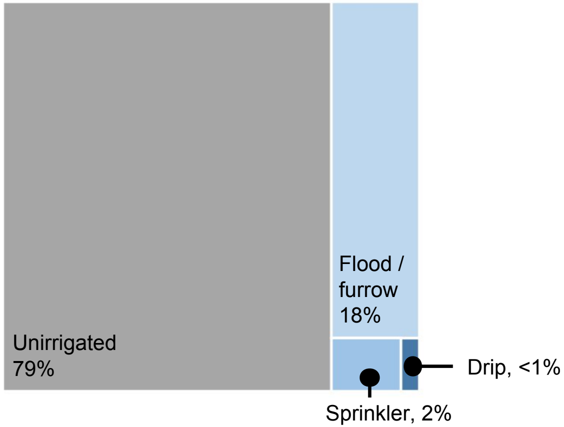
Drip irrigation can reduce water consumption by 20-60% compared to flood, furrow, and sprinkler irrigation. [2-5]

Additional benefits of drip may include high water distribution uniformity across a field, reduced fertilizer use, and reduced weed growth.

[1] Searchinger et al., 2019, *WRI Report*.
[2] Hanson et al., 1997, *Ag Wat Mgmt.*
[3] Cetin et al., 2002, *Ag. Wat. Mgmt.*
[4] Maisiri et al., 2005, *Phys. And Chem. of the Earth*

Design and validate low-cost, low-pressure, high-performance drip irrigation systems for smallholder farmers.

Irrigation status of cultivated land [1]

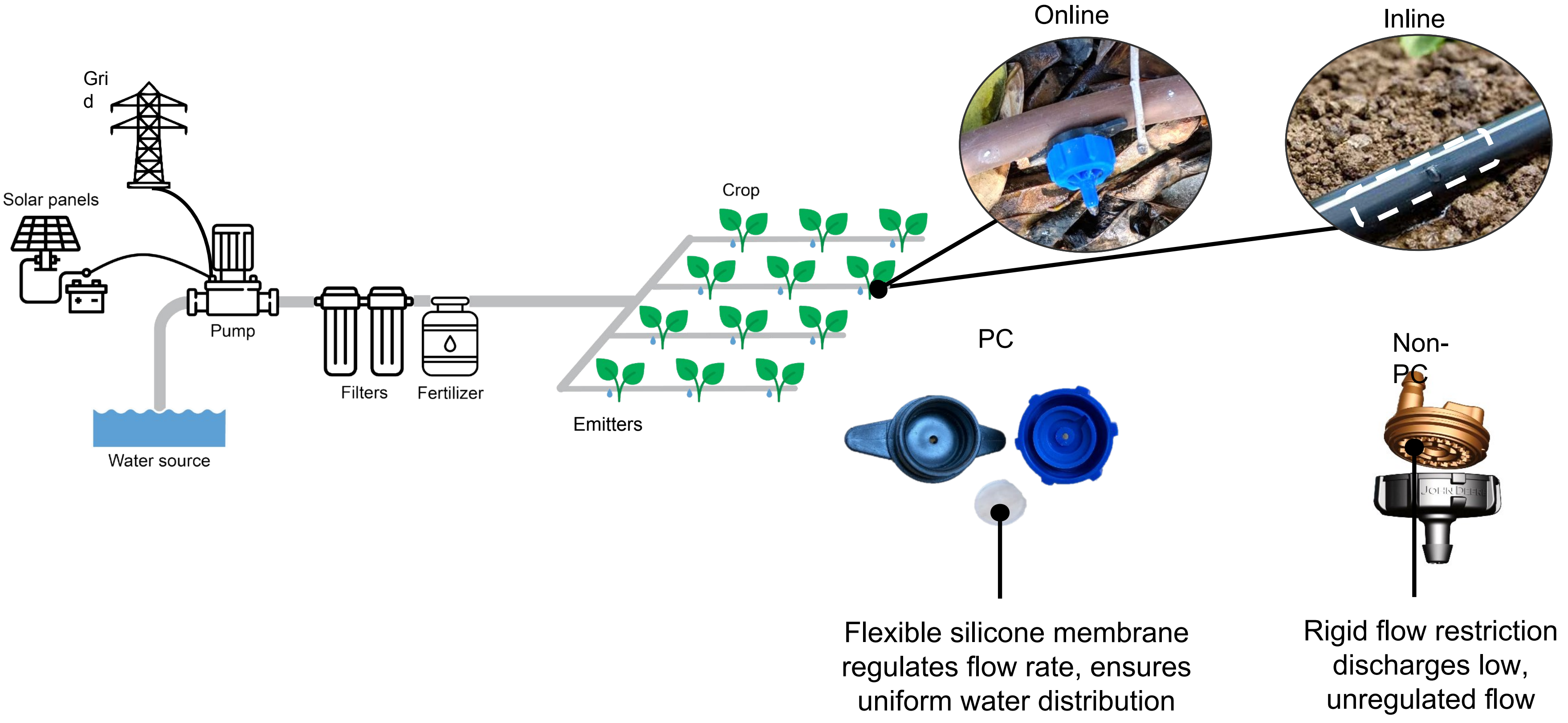


Drip adoption is limited by high capital cost.

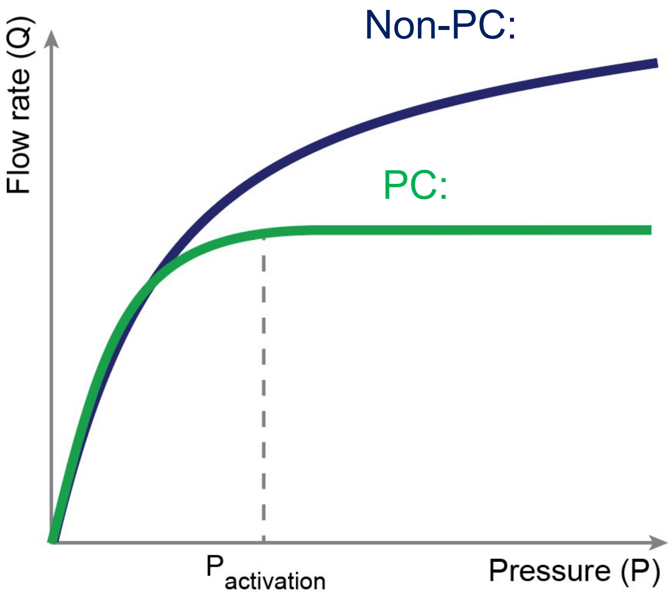
Low-pressure systems can reduce operating costs of grid-powered systems or capital costs of renewable-powered systems.

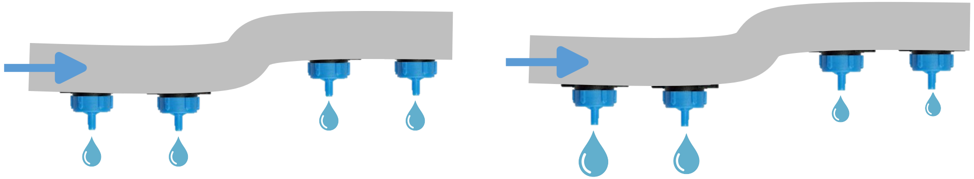
[1] FAO, 2012, AQUASTAT.

Pressure-compensating (PC) emitters discharge a constant flow rate across a range of pressures



Flow regulation of PC emitters promotes uniform water distribution to all crops in a field





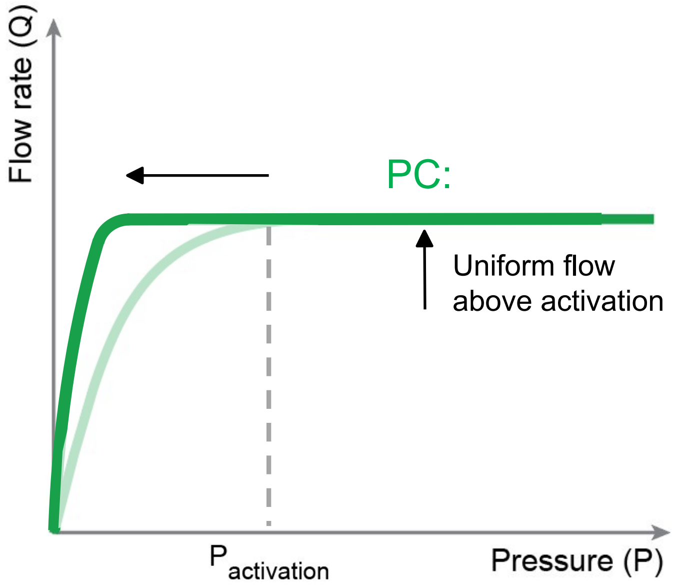
PC

Flexible silicone membrane regulates flow rate, ensures uniform water distribution

Non-PC

Rigid flow restriction discharges low, unregulated flow

We aim to reduce the activation pressure of PC emitters without affecting their distribution uniformity

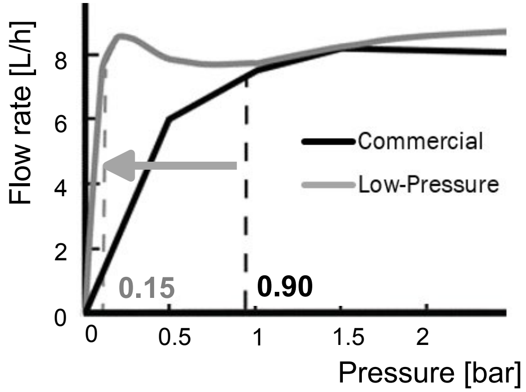


PC

Flexible silicone membrane regulates flow rate, ensures uniform water distribution

Field validation of low-pressure online pressure-compensating (PC) emitters

GEAR Lab designed and prototyped an online PC emitter with activation pressure of 0.15 bar, 70-83% lower than in commercial emitters. [1,2]



Research goal

Quantify the value low-pressure emitters can provide to farmers through measurements of emitter performance (energy use, emission uniformity) in field conditions.

[1] Shamshery et al., 2017, *PLoS One*, 12:e0175241.
[2] Shamshery and Winter, 2017, *ASME J. Mech. Des.*, 140(3).

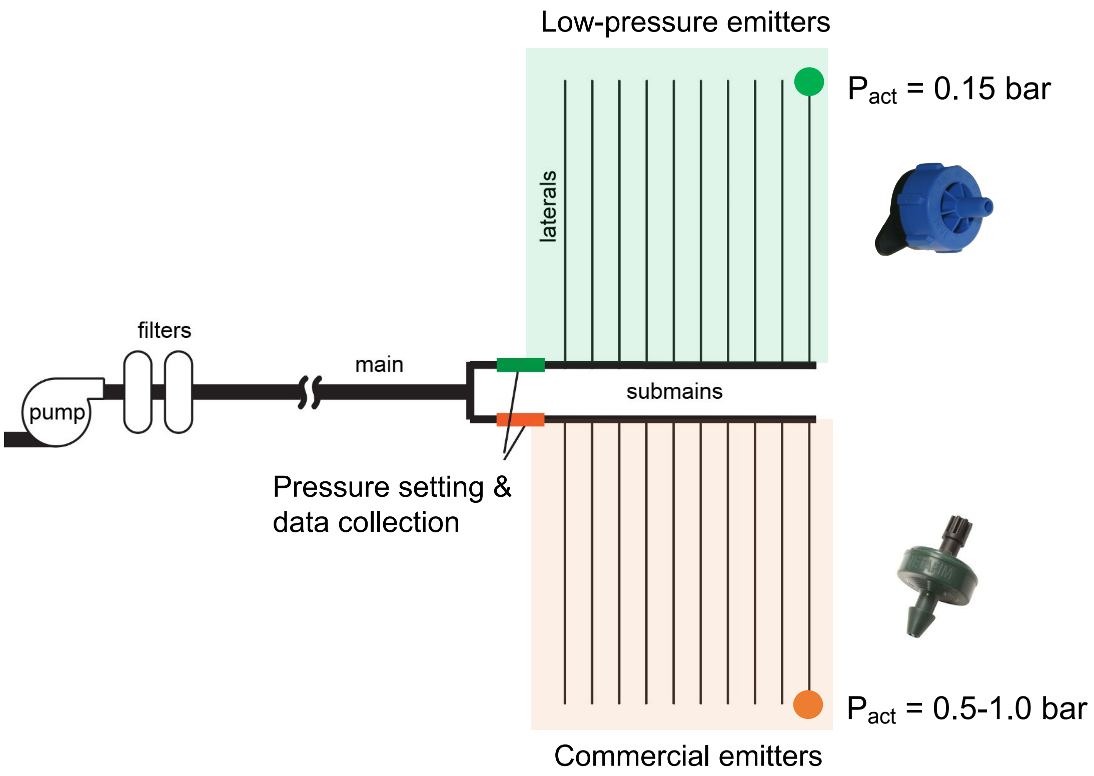
Performance in field pilots is a better predictor of emitters' value to users than lab tests

Large sample size	
Extended timeline	
Varied water sources	
Varied crops and irrigation scheduling	
Local maintenance practices	

Field pilots sites encompassed a variety of operating conditions

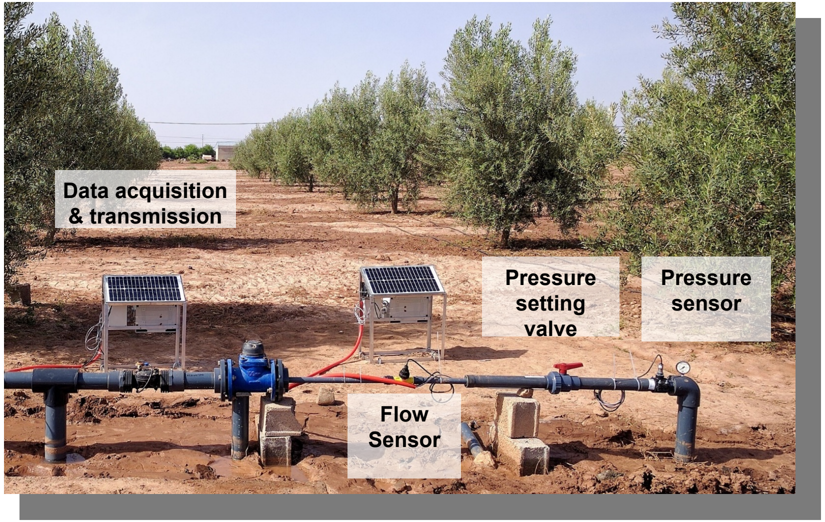
Large sample size	9 sites in Morocco and Jordan 5000+ emitters
Extended timeline	1-3 years April - Nov
Varied water sources	Groundwater Canal water Treated wastewater
Varied crops and irrigation scheduling	Olives Citrus Pomegranates
Local maintenance practices	Farm managers continued typical operation

Low-pressure emitters were tested alongside commercial emitters, each operated at the minimum pressure



Sokol, J., et al., 2019, *Water*, 11:1195-1224.

Sensors were used to monitor hydraulic energy at the entrance to each subunit

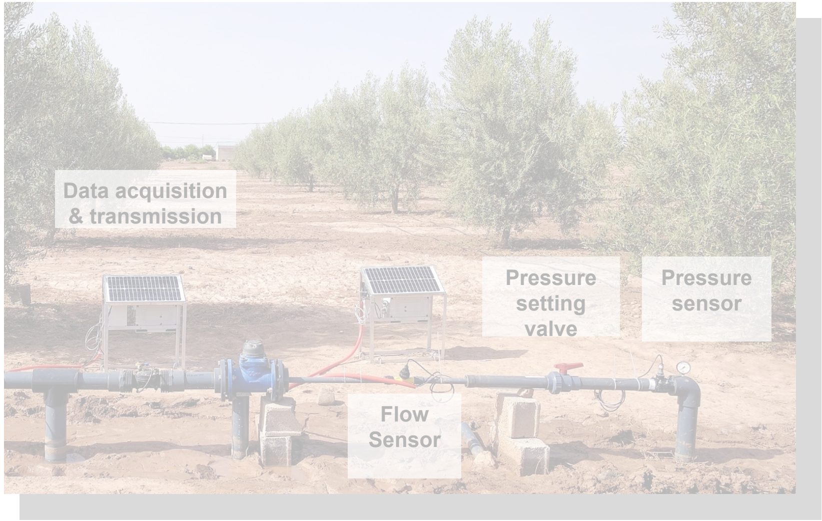


Specific hydraulic energy:

hydraulic energy per volume of water delivered

Sokol, J., et al., 2019, *Water*, 11:1195-1224.

Water distribution uniformity was measured regularly from 32 emitters on each plot



Specific hydraulic energy:

hydraulic energy per volume of water delivered

Statistical uniformity: SU

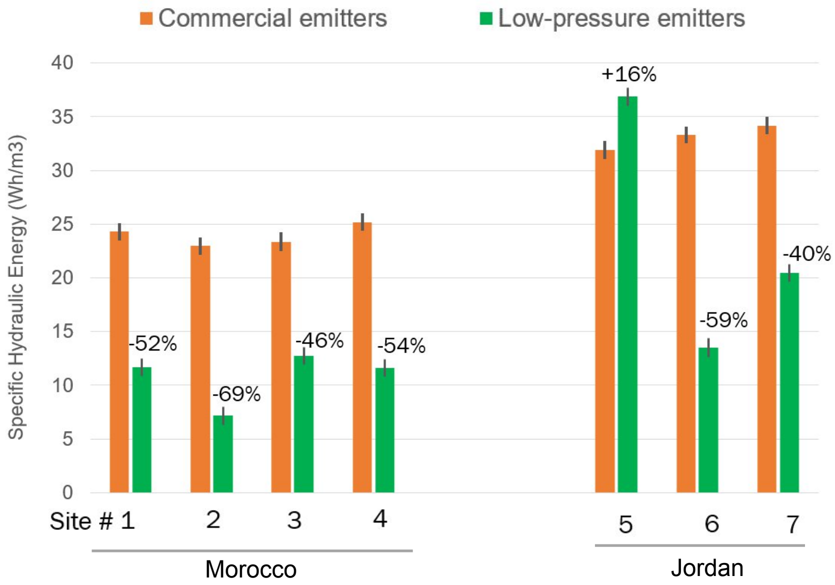
variation in flow rate across emitters in one plot, due to manufacturing, pressure differences, and/or clogging

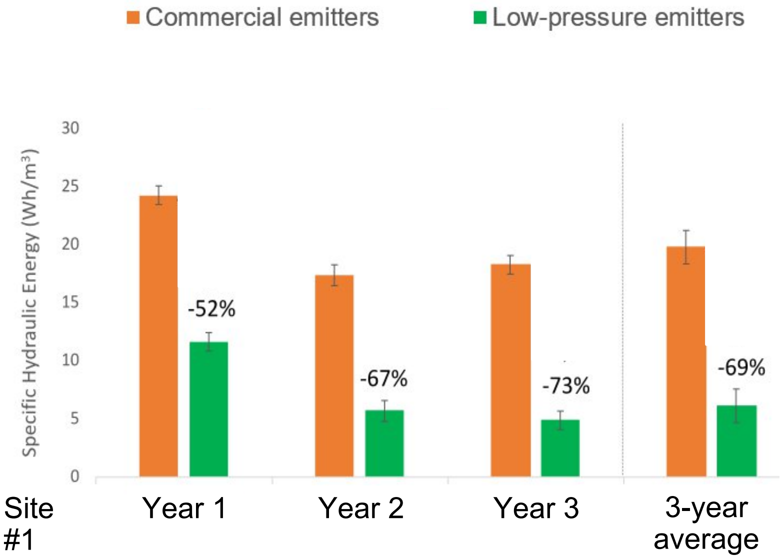
← Standard deviation of emitter flow rates

← Mean of emitter flow rates

Sokol, J., et al., 2019, *Water*, 11:1195-1224.

Field data showed reductions of 40-73% in hydraulic energy between commercial and low-pressure emitters



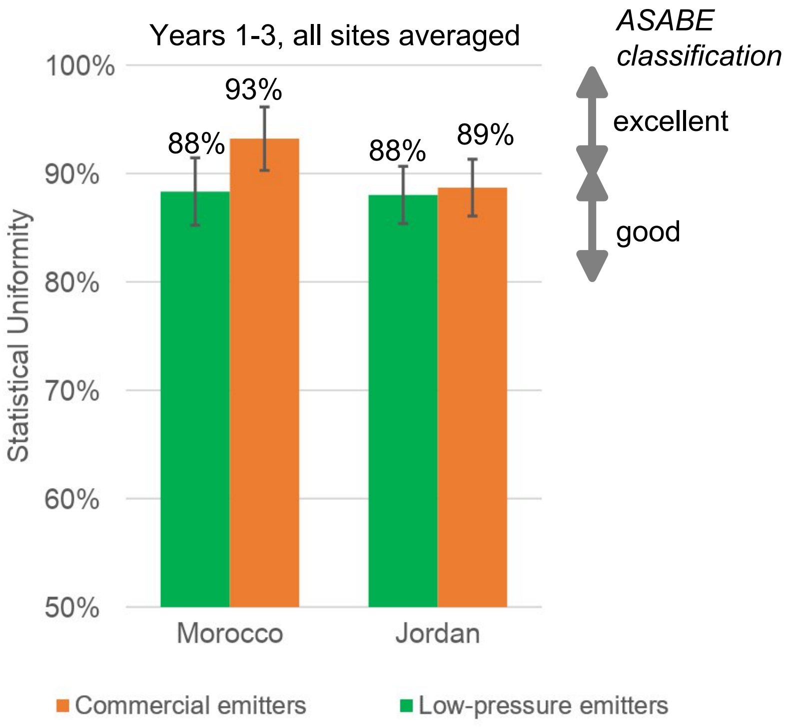


Average 43% reduction in hydraulic energy across all sites in year 1.

Higher energy savings in years 2-3 due to more consistent pressure regulation. **Average 69% reduction over 3 years.**

Sokol, J., et al., 2019, *Water*, 11:1195-1224.

Field uniformity was consistent over time and comparable to that of commercial emitters



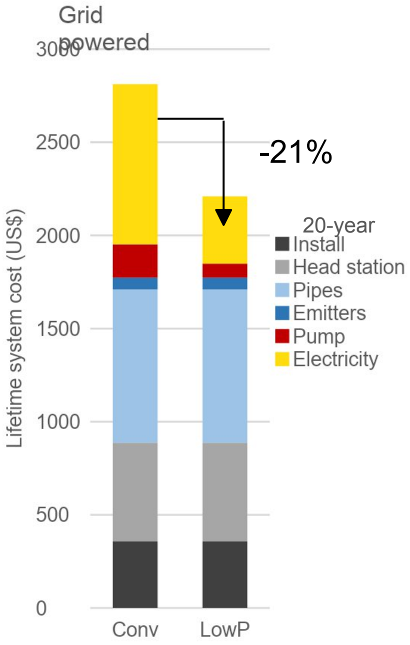
No reduction in uniformity over time under regular maintenance.

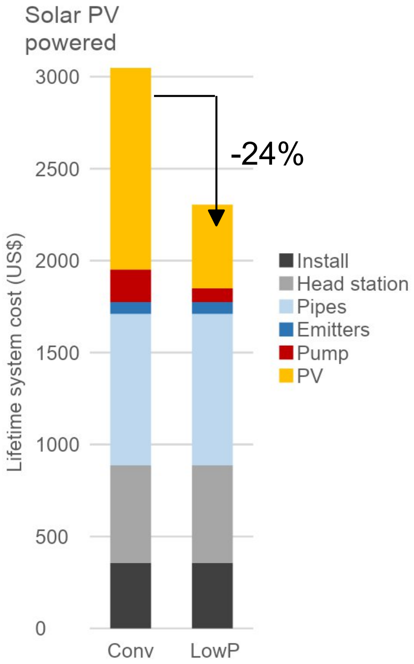
Comparison to lab tests showed that manufacturing variation accounts for nearly all field non-uniformity.

Enhanced quality control in manufacturing should improve performance.

Sokol, J., et al., 2019, *Water*, 11:1195-1224.

Energy savings translate to 21-24% reduction in lifetime system cost, based on Morocco case



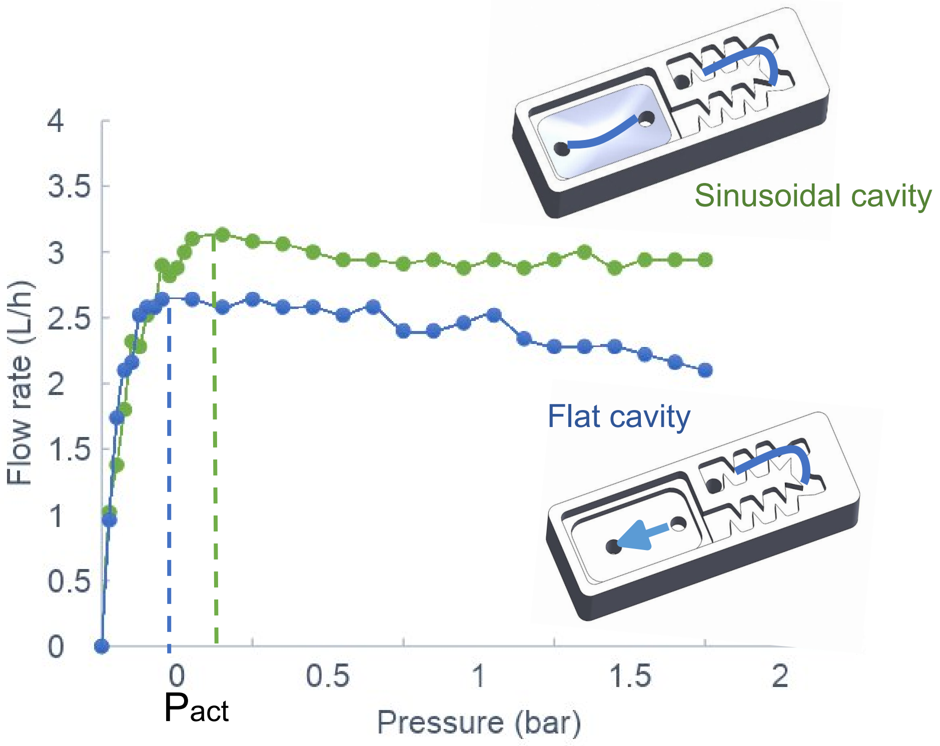


58% reduction in energy or solar array **costs paid by the farmer**

Costs covered under Moroccan **government subsidy**

Based on 3/4 ha citrus farm in Morocco with a surface water source
Pump flow rate = 5.2 m^3/hr. Pump pressure: Conv = 1.4 bar; LowP = 0.6 bar.
Component costs from local contractor invoices. Replacement cost for laterals and emitters included.
Other costs: electricity = \$0.107/kWh; PV = \$1.0/Watt-peak; pump = \$450/W; pump efficiency = 50%.

Channel-less emitters with wider flow paths demonstrate PC behavior in experiments



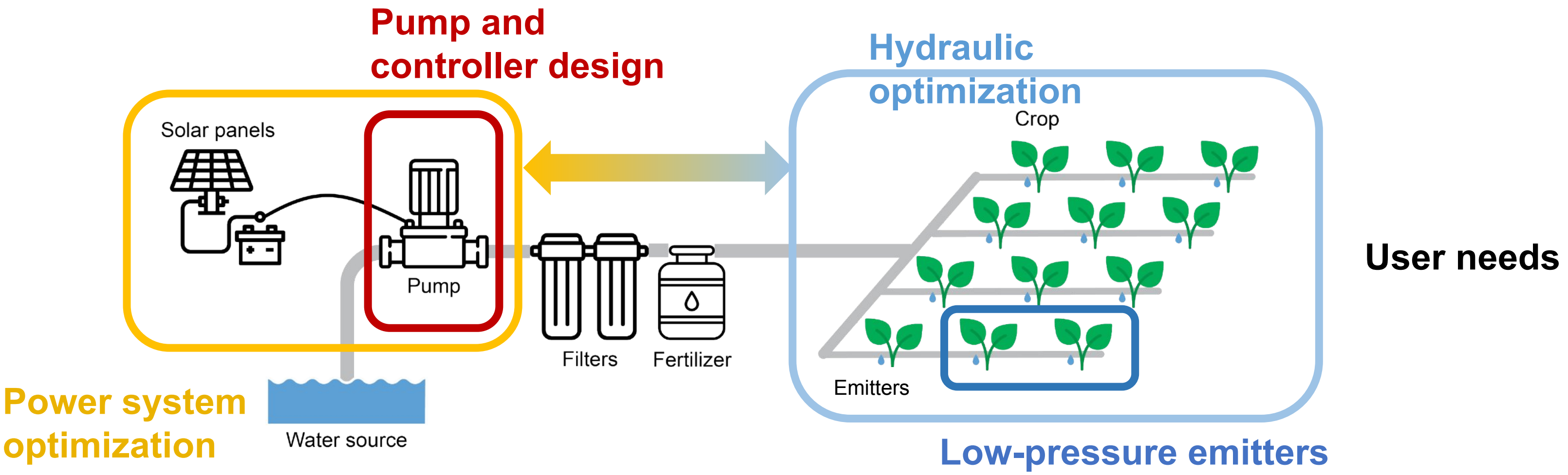
These architectures regulate flow as:

Deforming membrane conforms to the curved shape of the cavity bottom, increasing friction losses;

Minor loss at the outlet increases as its area is gradually covered by the membrane.

Larger geometric features may reduce risk of clogging and loosen the required manufacturing tolerances.

On-going research targets further cost reductions through system-level optimization



Thank you